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An Activity Analysis Model of the Soviet Iron and Steel Industry

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A Technical Intelligence Report

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A Technical Intelligence Report

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An Activity Analysis Model of the Soviet Iron and Steel Industry

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Summary

Information available as of 1 June 1983 was used in this report.

At least through the mid-1980s lagging steel production could be the most important impediment to Soviet economic performance. Problems in this branch could thwart Soviet plans for expansion of output of consumer durables and investment goods while meeting targets for the production of military hardware and maintaining exports, primarily to Eastern Europe.

By the mid-1970s the Soviet iron and steel industry was the largest in the world—surpassing crude steel production of the United States and accounting for more than one-fifth of world steel output. Despite its size and strategic importance, crude steel production in 1975 was below the official target, reflecting shortages of both material resources and furnace capacities. The failure of iron ore production to grow as planned and underinvestment in upgrading blast furnaces caused a shortfall in pig iron production that, together with stagnation in scrap metal availability, contributed to a 5-million-ton shortfall in both crude and finished rolled steel. The situation has not improved. In 1982 Soviet crude steel production was 147 million tons (mt), over 5 mt below peak year output in 1978 and 21 mt below the 1982 target.

Much speculation exists concerning the relative importance of the two principal factors—inadequate steel furnace capacity and insufficient allocation of material resources to ferrous metallurgy—causing this shortfall. This paper shows how an economic model can estimate the importance of these two factors. Our analysis suggests that the shortfall in crude steel production in the early 1980s can be explained primarily by inadequate furnace capacity.

Although the USSR plans to increase investment in the steel industry by almost one-third in the 1981-85 period compared with that in the 1976-80 period, the goal probably understates the amount of new investment required to achieve the necessary growth in capacity. Moreover, because of the long gestation periods for bringing new capacity on line, even with a step-up in investments in the near term, imbalances in capacity among the components of the industry—iron ore, coking coal, crude steel, and finished steel—are unlikely to be eliminated over the next several years.

Raw materials shortages also will interfere with plans to modernize steelmaking capacity, resulting in the inefficient use of raw materials, energy, and labor. For example, a longstanding Soviet objective is to replace a large share of older open-hearth furnaces with the more efficient basic oxygen and electric furnaces predominant in the rest of the world.

SOV 83-10151
August 1983

However, the unpredictability of raw material supplies will force the Soviets to maintain current levels of open-hearth capacity since pig iron and scrap metal are completely substitutable in such furnaces.

In view of limitations on production capacity and resource availability, our base case estimate of crude steel production in 1985 is roughly 156 mt, over 6 percent more than crude steel output in 1982 but nearly 8 percent less than the Soviet target.

We studied the sensitivity of our estimate of Soviet production in 1985 to:
- Technological improvement: a lower coking rate in blast furnaces.
- Energy conservation: reduced fuel oil allocation to the ferrous metals industry.
- External influence: stoppage of Polish coking coal exports to the USSR.

Under these assumed conditions, our analysis of steel production in 1985 shows that:
- If a 1.5-percent average annual reduction in the coking rate were attained, the Soviets would be able to produce an additional 2.3 mt of crude steel, increasing total output 1.5 percent.
- If the allocation of fuel were reduced 15 percent from our base case level, steel production would be cut about 2 mt, a 1.3-percent decrease in total steel output.
- If Polish coking coal imports were stopped and the Soviets did not offset this loss from other sources, crude steel production would be cut by some 5 mt or 3 percent from the 1985 estimate.

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Contents

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An Activity Analysis Model of the Soviet Iron and Steel Industry [redacted]

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Introduction

This report identifies the problems of the Soviet ferrous metals industry during the 1975-85 period, using a regional linear programing model. After validating the model, a series of illustrative analyses is developed to show how the model yields important information about the behavior of the industry—information that cannot be obtained directly from official data or through other analytic tools. In particular, the model quantifies the major causes for the poor performance of the steel industry in 1980 and predicts, under assumed operating practices and plans, performance during the 1981-85 Plan. A base case is used to assess the impact on our estimate for 1985 of possible technological change, domestic policy shifts, and external influences.

The model has been used previously to help identify the causes of the poor performance of the Soviet iron and steel industry.[1] It also has been used to estimate Soviet needs for coking coal in 1985 and to assess the impact on Soviet steel production of the stoppage of Polish coal exports to the Soviet Union.[2]

There are certain limitations in the use of the model. In particular, its primary purpose is to quantify major resource constraints on inputs used to produce iron and crude and rolled steel. The model assumes bounds on the capacities of crude steel furnaces, but the capacity of rolling mills is unconstrained and the finishing and specialty steel stages of production are not modeled. Moreover, the model implicitly assumes a balance throughout all stages of production at each steel plant. In practice, imbalances occur for a variety of reasons, including the planned and unscheduled downtime related to maintenance of equipment; the modernization and/or replacement of existing equipment; and the forced stoppage or slowdown in production caused by inadequate electric power, fuel, or raw material supplies. Although not addressed in this study, there is evidence of additional capacity constraints at the rolled steel stage and/or later stages of production. Soviet imports of finished rolled steel and specialty steel products suggest chronic shortages in domestic capacities as well as inadequate quality control procedures to produce these products at required specifications, or in the required volumes.[3]

Model Structure

The regional linear programing model is "static" in the sense that it describes the operation of the industry for a particular year, for example, 1975, 1980, and 1985. The growth path of the industry can be studied, however, by comparing results from the model for 1975 with results for 1980 and 1985.

The structure of the model includes:

- *Constraints* that specify regional resource availabilities of fuels and raw materials from both domestic sources and imports, rolled steel production targets, deliveries of iron and steel products to foundries, and exports of intermediate products.
- A *production block* that quantitatively describes ironmaking and steelmaking at mills in all regions of the USSR.
- A *transportation block* (linked to the production block) that mathematically defines the regional railroad and gas pipeline networks.
- An *objective function* that serves as the financial target for operation of the industry.

[redacted]

[3] "The Soviets claim greater priority will be given to modernization and quality improvement during the current plan. Such claims, however, have been a hallmark of Soviet plans since the mid-1960s. Given the long leadtimes required to construct new rolling mills (seven to 10 years), it is doubtful whether much progress can be made during the 1980s." [redacted]

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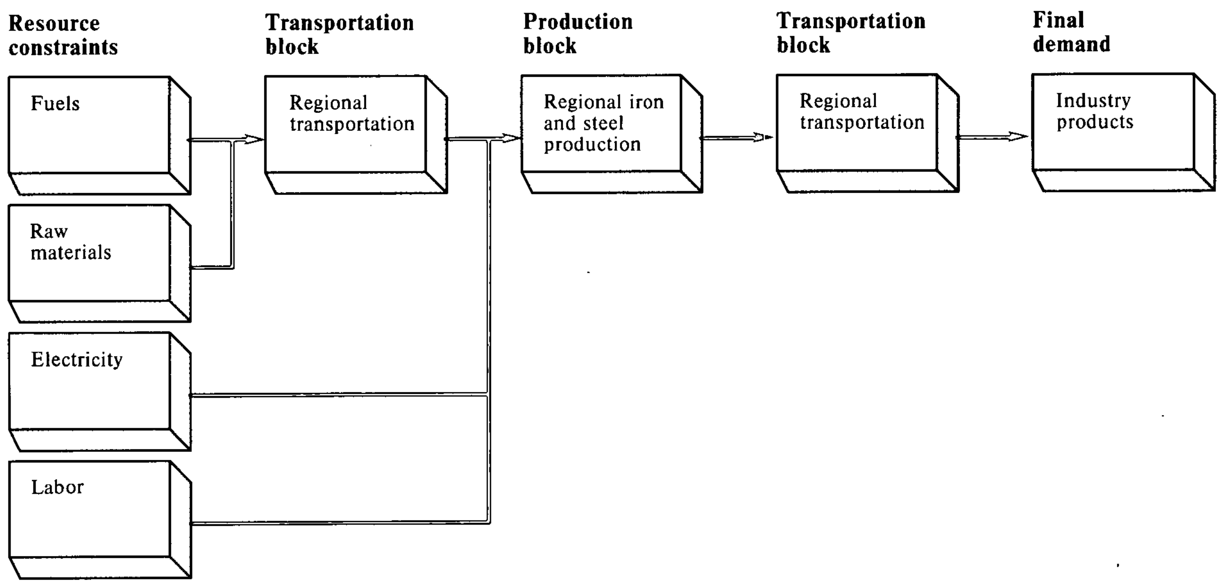
Figure 1
USSR: Iron and Steel Industry Model



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A flow chart illustrates the relationships among the resource constraints, production and transportation blocks, and final demand for rolled steel (see figure 1).

Theoretical Aspects of the Model

Linear programing simultaneously solves two distinct problems called the primal and the dual. The optimal solution of the primal problem indicates the production levels and resource allocation pattern among iron and steel mills that will result in production of a specified level of rolled steel in a particular year at the minimum total variable (labor, material, energy, and transport) costs.

The solution of the dual problem provides valuable information in the form of so-called shadow prices. These prices are simultaneously determined with the value of the objective function and the optimal level of resource use. Shadow prices are synthetic or artificial prices that would prompt efficient allocation of resource inputs and transport services to produce a given pattern and level of output. Although prices are less important in the USSR than in a market economy in determining the actual pattern of resource allocation, the dual solution is especially useful for testing the validity of the structure of the model and for evaluating the economic efficiency of the Soviet iron and steel industry.

The Primal Problem

The primal problem can be stated formally as:

$$\text{Minimize} \quad Z = C'X \tag{1}$$

$$\text{Subject to} \quad AX \leqq B \tag{2}$$

$$\text{and} \quad X \geqq 0 \tag{3}$$

Where

A is an *m* x *n* partitioned matrix of input-output coefficients describing activities in the production and transportation blocks,
C is an *n* x *1* vector of unit resource costs and freight tariffs,
X is an *m* x *1* vector of activity levels in production and transportation operations.
B is an *m* x *1* vector of resource restrictions and output targets, and
$Z = C'X$ is the objective function to be minimized, where this function is total variable cost.

The model assumes that the industry acts as a unit to minimize the variable cost of producing a given set of iron and steel products. Thus, it postulates the industry acting as if it were a monopoly directed by a central planning authority that assigns production goals to regions subject only to production capacities and technologies and to resource allocations to ferrous metallurgy. The model assumes that there is no responsiveness of planned output to price and that resources are substitutes within strict limits determined by technological conditions.

Production Block
The production block is a mathematical representation of the major production activities in ferrous metallurgy. These activities are shown in figure 2. Each activity defines a unique relationship between an output and a number of inputs to portray production functions for a number of intermediate and final products of ironmaking and steelmaking (for example, pig iron, crude steel, and rolled steel). These relationships (input-output coefficients) are assumed to be representative of production practices in the Soviet Union. The coefficients indicate particular resource requirements per unit of product in physical units (for example, kilograms of coke per metric ton of pig iron). They are collected in the A matrix (see equation 2, page 3, of the primal problem) with each column of the A matrix pertaining to a given production activity and each row of the A matrix referring to a given resource.

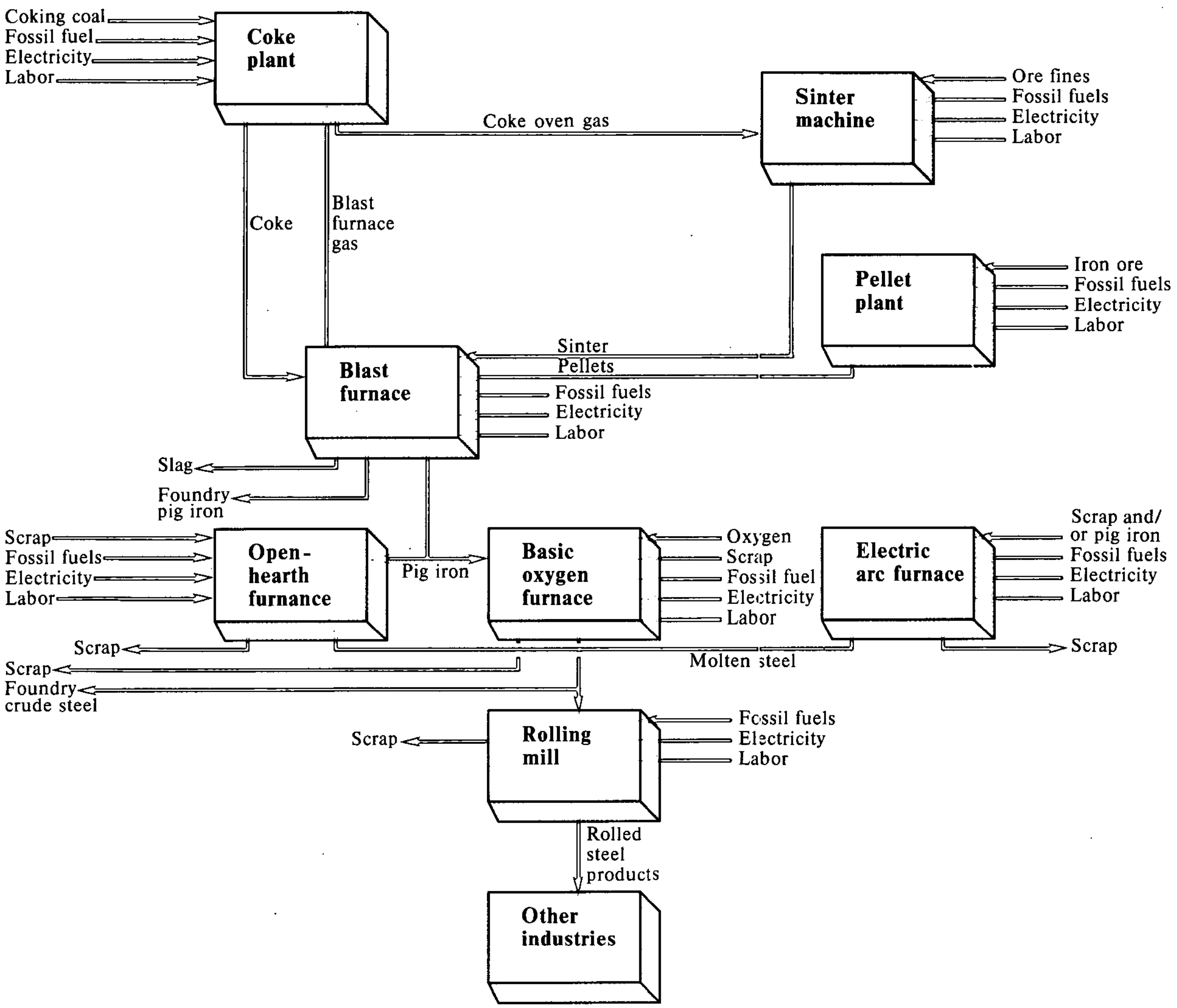
The production block also includes a number of other activities. These involve the purchase and sale of resources consumed in ironmaking and steelmaking, including imported resources and the export of resources and products (for example, coke, iron ore, and pig iron).

Transportation Block
The transportation block includes railroad and pipeline transport activities that mathematically represent routes used to haul fuel and material resources between sources of supply and steel mills. These activities are described analytically in the coefficient matrix (A) of the model (see equation 2, page 3, of the primal problem). Distances between sources and steel plants are measured in kilometers along an actual route. Hard coal, coking coal, fuel oil, iron ore, scrap, and cold metal are hauled by railroad, and natural gas is transmitted by pipeline.[4] An example of such an activity is the railroad shipment of hard coal from Vorkuta area mines to the Cherepovets steel plant in the Northwest region, via Vologda (a major terminal on the route)—roughly 1,900 km.[5]

Constraints
The model includes the vector (B) of regional constraints (see equation 2, page 3) on the allocation of resources to ferrous metallurgy, on the required production of rolled steel, on the shipment of iron and steel products to Soviet consumers outside the ferrous

[4] In this paper *hard coal* refers to bituminous coal not used for coking.
[5] The model explicitly accounts for resource losses in transit. Assumed losses per unit of resource shipped are coal, 5 percent; fuel oil, 3 percent; natural gas, 5 percent; and iron ore, 5 percent.

Figure 2
USSR: Selected Activities and Resource Flows in Iron and Steel Production



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metallurgy industry, and on the import and/or export of material resources and iron and steel products. A unique vector of constraints is defined for each year studied.

Resource consumption constraints limit the total allocation of a particular resource to no more than its production minus its allocation to other domestic users, to net transport losses, and to net exports (inventories are assumed unchanged). Resource constraints for coking coal, iron ore, and ferrous metal scrap are presented in a technical working paper.[6] The availability to the iron and steel industry of other resources such as fuel oil, natural gas, and limestone is assumed to be unconstrained except when otherwise indicated in the analysis.

Rolled steel production is constrained in the model so that total output equals a specific level as reported in the working paper. This level could be a maximum level given the availability of resources, a planned level reported by the Soviets, or an estimated level suggested by analysis outside the model. Constraints also are defined on the maximum import of resources consumed and on the required export levels of some resources and products of ferrous metallurgy (see the working paper).

Bounds

Upper and lower bounds are defined on crude steel output by type of furnace in each region.[7] These bounds reflect utilization of estimated annual steel furnace design capacity. The upper bound is 105 percent; the lower is 92 percent of nominal capacity. Without these bounds, the solution to the model would be a profit-maximizing one in which inefficient, relatively high-cost methods of steel production may not be used, or, more typically, they would be operated at considerably less than capacity.

Objective Function

Our model assumes the objective function to be the criterion Gosplan and Ministry of Ferrous Metallurgy officials use to evaluate alternative solutions. It assumes that decisionmakers minimize total variable costs resulting from the production of the maximum feasible level of rolled steel in a specific year or the planned rolled steel production goal for a particular year (see equation 1, page 3), subject to a set of regional resource and other constraints (see equations 2 and 3, page 3). The function assumes constant average unit costs of inputs at sources of resource supply and constant average unit costs of transportation.[8]

Geographic Dimension

The model includes descriptions of steelmaking operations in 12 different regions as well as transportation links between them (see figure 3). The geographic regions defined in the model are listed below along with the 19 corresponding officially designated economic regions:

Regions in the Model	Soviet-Designated Regions [a]
Northwest	Northwest
Baltic	Baltic
	Belorussia
Central	Central Industrial
	Central-Chernozem
	Volga-Vyatka
Southern	Southwest Ukraine
	Donets-Dnepr
	Southern Ukraine
	Moldavia
Volga	Volga
Urals	Urals
Caucasus	North Caucasus
	Transcaucasus
Kazakhstan	Kazakhstan
Central Asia	Central Asia
West Siberia	West Siberia
East Siberia	East Siberia
Far East	Far East

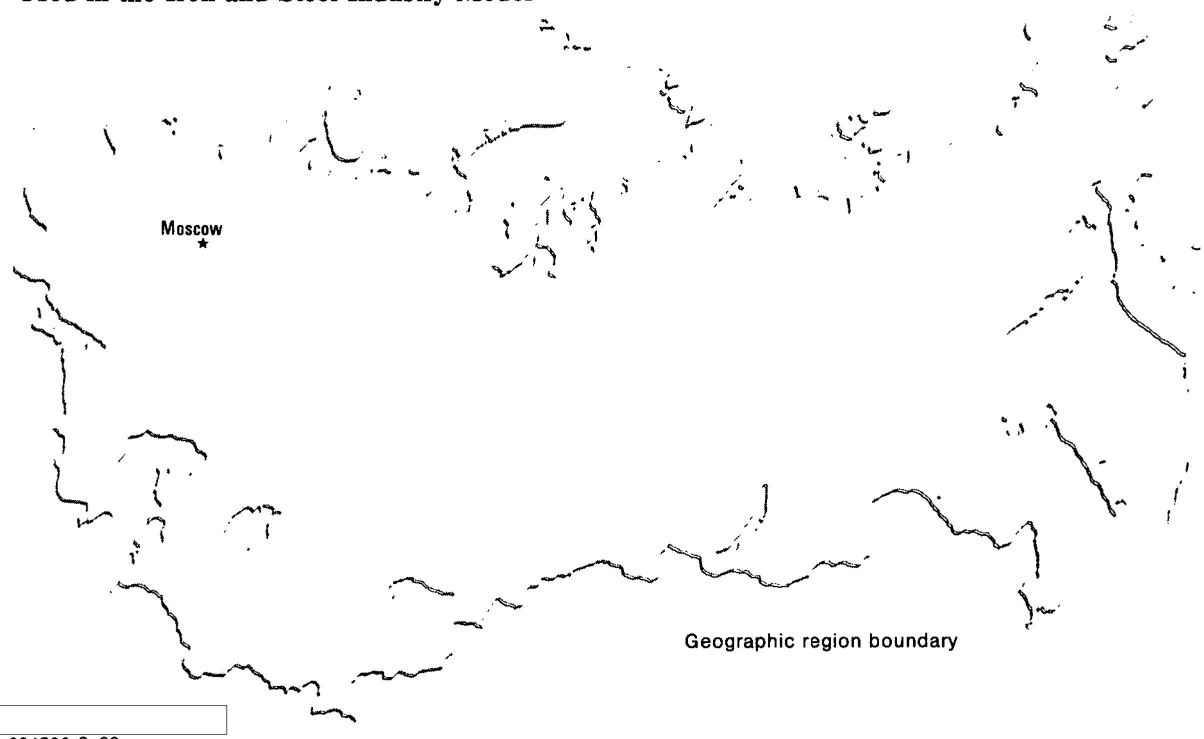
[a] Used by Soviet planning organizations.

[6] The data used to construct our regional model of the Soviet iron and steel industry are available upon request.

[7] Imposing bounds on the model restricts it to a suboptimal solution. That is, bounding the solution is a major qualification on a strictly cost-minimizing model required in this case because the Soviets operate most furnaces near capacity regardless of relative cost efficiency.

[8] The cost of labor, fuels, electricity, and material resources used in ferrous metallurgy and the cost of transporting resources are presented in the technical working paper.

Figure 3
USSR: Geographic Regions
Used in the Iron and Steel Industry Model



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The geographic dimension is crucial to understanding the difficulties planners face with resource allocation and conservation in ferrous metallurgy. Although steelmaking is found in all regions, the resource base supporting the ferrous metals industry has been shifting from the Ukraine and Urals to the Central and Northwest regions and to West Siberia and Kazakhstan (figure 4).[9]

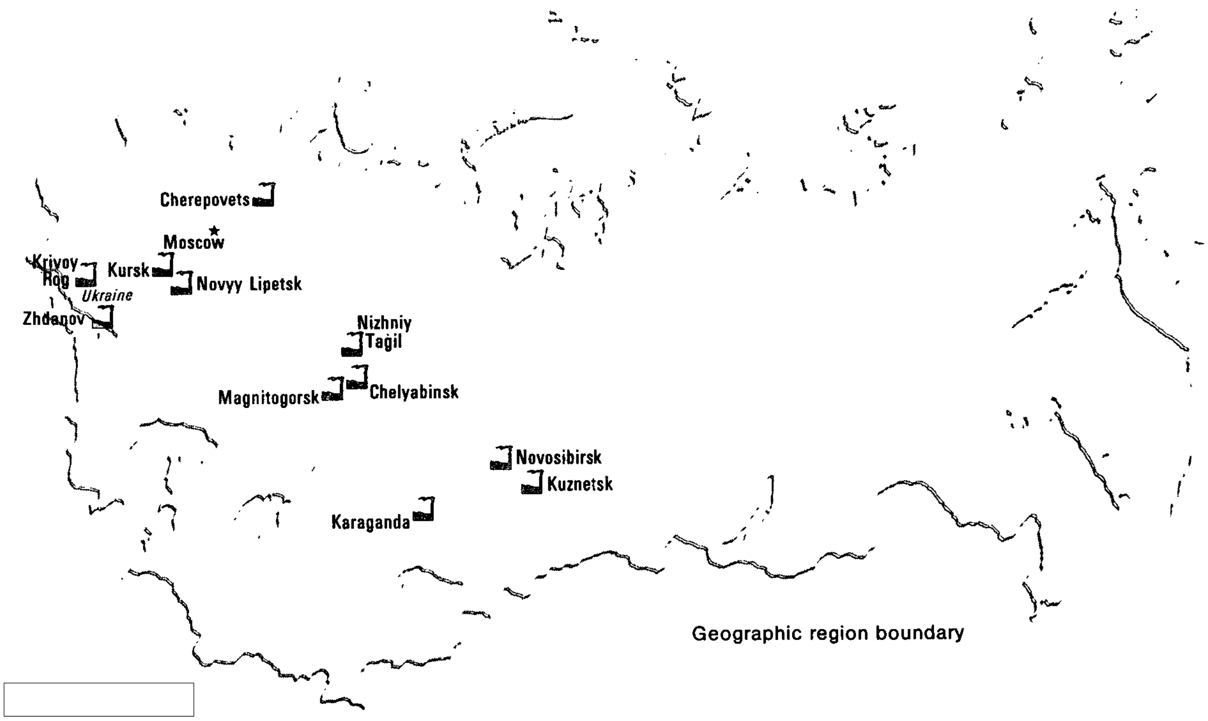
In recent years the average rail haul of iron ore and coal has been increasing annually at roughly 1 and 3 percent, respectively. About one-third of the annual iron ore output of the Kursk Magnetic Anomaly in the Central region (about 13 million tons) must be shipped over 1,000 km to blast furnaces in the Urals. Additional amounts of ore must be shipped over 3,000 km to the Urals from the Kola Peninsula (in the Northwest region). West Siberia also has been increasing its dependence on iron ore from other regions; about 3 million tons of ore must be shipped roughly 2,500 km to Novokuznetsk from deposits near Rudnyy in Kazakhstan. In addition, because coal output is declining in Donets mines, the Soviets are now hauling coking coal about 4,000 km from the Kuznetsk in West Siberia to blast furnaces in the Ukraine. This is equivalent to shipping coking coal by rail from Spokane to the Bethlehem Steel plant at Sparrows Point near Baltimore.

Description of the Soviet Iron and Steel Industry in 1975

This section briefly summarizes the output and fuel consumption performance in ferrous metallurgy in 1975 and it provides some perspective for understanding its problems and prospects in the 1981-85 Plan period suggested by results of our model.

[9] Two regions, the Southern and the Urals, together produce about two-thirds of Soviet crude steel output.

Figure 4
USSR: Major Iron and Steel Plants



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USSR: Major Iron Ore and Coking Coal Deposits

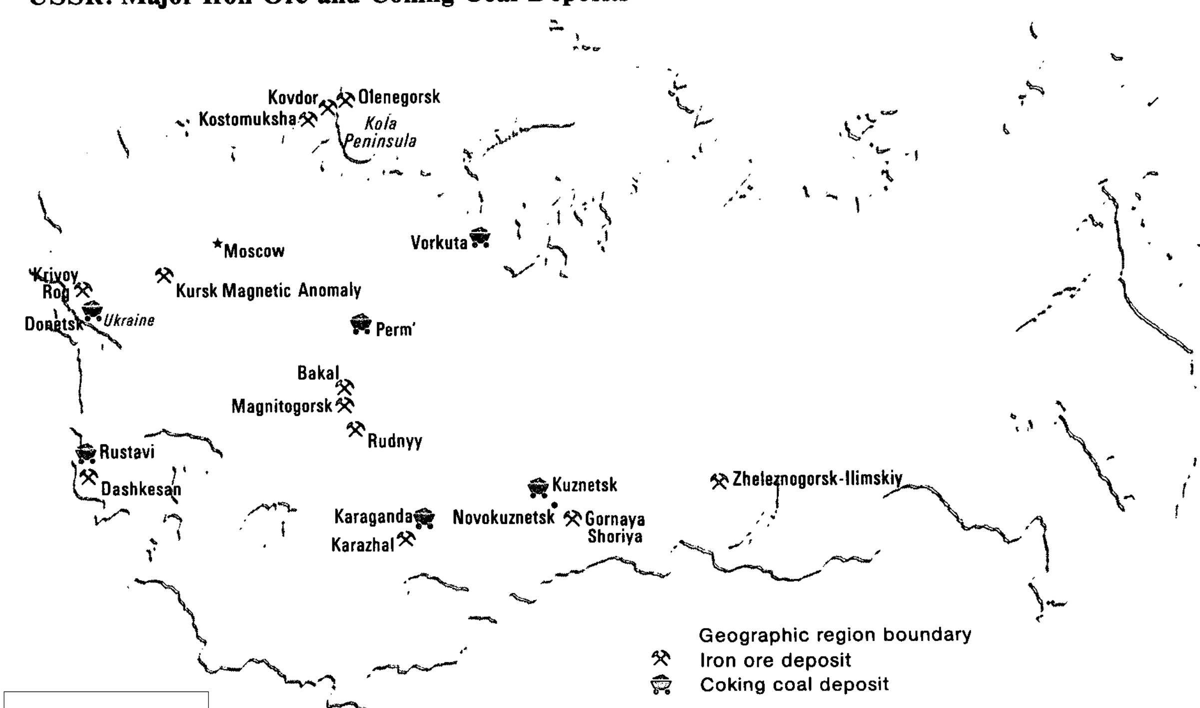

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Table 1
USSR: Ferrous Metals Industry:
Output Targets and Actual Production, 1975

Item	Plan	Actual	Shortfall (percent)
	Million metric tons		
Iron ore	248.0	234.7	5.4
Pig iron	108.5	103.0	5.1
Crude steel	146.4	141.3	3.5
Finished rolled steel	103.5	98.7	4.6

Table 2
USSR: Ferrous Metals Industry:
Fuel, Electricity, and Energy Consumption, 1975 [a]

	Total *(million metric tons of standard fuel)*	Per ton rolled steel *(kilograms of standard fuel)*
Fuel	167.1	1,453
Electricity [b]	32.2	280
Total energy	192.8	1,677

[a] Source: I. P. Kurnosov and T. I. Klokova, *Gazosnabzheniye narodnogo khozyaystva v ix pyatiletke* (Moscow: Vniiegazprom, 1977), page 22.
[b] Total electricity consumption and consumption per ton of rolled steel in kWh were converted to standard fuel using the countrywide average fuel consumption per kWh for 1975 of 340 grams reported in *Narodnoye khozyaystvo*, 1922-82, page 180. Because we used the countrywide average figure for fuel consumption per kWh, fuel and electricity consumption do not equal total energy consumption.

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Production

In 1975 the Soviet steel industry was the largest in the world—surpassing crude steel production of the United States and accounting for about 22 percent of world steel production. Despite its size and strategic importance in the Soviet economy, crude steel production was below the official target for that year because of shortages of both material resources and furnace capacities. Iron ore production, for example, was 235 million tons (mt)—13 mt less than planned production of 248 mt for 1975 (see table 1). The failure of iron ore production to grow as planned and Soviet underinvestment in expanding blast furnace capacity caused a 6-mt shortfall in pig iron production from the planned level for 1975. This shortfall together with the stagnation in scrap metal availability in the range of 75-77 mt during the mid-1970s contributed to below-plan production of both crude and finished rolled steel of roughly 5 mt each for 1975.

Energy Consumption

Ferrous metallurgy is energy intensive, consuming more than 10 percent of all fuels extracted and about 9 percent of total electricity generated in 1975 (see table 2). The Soviets have made noteworthy progress in conserving energy in ironmaking as evidenced by steady reductions in the coking rate (the amount of coke consumed per ton of pig iron). These economies have been achieved by a variety of measures. Great attention has been given to improving the charge to the blast furnace. Also, operating practices have been improved at both old and new furnaces, for example, by using injections of oxygen and natural gas. And for many years the Soviets have been leaders in building increasingly larger furnaces incorporating advanced operating practices.

The quantity and mix of fuels consumed in ironmaking and steelmaking reflect, in part, the structure of production, technological levels, and relative fuel prices in 1975 (see table 3). Steam coal was used mainly to generate electricity and steam at captive power stations.[10] Coke accounted for about 38 percent of total fuel consumption; it was both a source of heat and a chemical agent in ironmaking. Fuel oil was used mainly to heat crude steel furnaces and in production of rolled steel. Gas, including natural and secondary gases, was the most important fuel consumed in steelmaking in 1975; it accounted for 50 percent of total fuel consumption.

[10] A *captive power station* is a heat and electric power station whose output is dedicated almost exclusively to a steel complex.

Table 3
USSR: Ferrous Metals Industry: Actual and Model Structures of Fuel Consumption, 1975

	Actual [a]		Model [b]	
	Million metric tons of standard fuel	*Percent*	*Million metric tons of standard fuel*	*Percent*
Steam coal	7.5	4.5	8.4	5.1
Coke	63.9	38.2	60.4	36.5
Fuel oil	8.1	4.8	8.2	4.9
Natural gas	39.6	23.7	46.0	27.8
Coke oven gas	17.8	10.7	14.9	9.0
Blast furnace gas	25.9	15.5	23.6	14.2
Other	4.3	2.6	4.2	2.5
Total	167.1	100.0	165.7	100.0

[a] Source: I. P. Kurnosov and T. I. Klokova, *Gazosnabzheniye narodnogo khozyaystva v ix pyatiletke* (Moscow: Vniiegazprom, 1977) page 22.
[b] Source: Model results.

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Validation of the Model

Validation is an important step in development and application, especially of large-scale computable models such as our Soviet ferrous metals industry model. In general, validation should establish the ability of the analytic construct to generate results consistent with the limited historical data available. This section provides a validation of the Soviet iron and steel industry model based on differences between model estimates and official Soviet data for 1975 on the consumption of fuels, electricity, and total energy; the consumption of material inputs; the cost of producing intermediate and final products; and the structure of the Soviet ferrous metals industry in 1975. The year 1975 was chosen for validating the model because it is the last year the Soviets published data in sufficient detail and volume.

Energy Consumption

Differences between actual and estimated levels of fuel, electricity, and total energy consumption in 1975 are important indicators of the reasonableness of the model as a positive description of the industry (see table 4). For the ferrous metallurgy industry, the difference between actual and estimated consumption using the model was: fuel, < 1 percent; electricity, < 10 percent; and total energy, < 1 percent.

Differences between the actual and estimated fuel consumption shares were also small (see table 3). Estimated shares of steam coal, fuel oil, and natural gas were slightly higher than the actual shares, and those of coke, coke oven gas, and blast furnace gas were slightly lower.

Material Consumption

The model was also validated by comparing estimates calculated outside the model and model results on the consumption of material resources in 1975. Processed iron ore (either in sinter or pellets) and steel scrap are the most important material inputs consumed in ferrous metallurgy:

- The estimated consumption of iron ore was less than 1 percent above that obtained using the model.

Table 4
USSR: Ferrous Metals Industry: Actual and Model Structures of Fuel, Electricity, and Energy Consumption, 1975

	Total *(million metric tons of standard fuel)*		Per ton rolled steel *(kilograms of standard fuel)*		Model as of actual in percent
	Actual [a]	Model [b]	Actual [a]	Model [b]	
Fuel	167.1	165.7	1,453	1,437	99
Electricity [c]	32.2	35.2	280	306	109
Total energy	192.8	194.4	1,677	1,686	101

[a] Source: I. P. Kurnosov, T. I. Klokova, *Gazosnabzheniye narodnogo khozyaystva v ix pyatiletke* (Moscow: Vniiegazprom, 1977), page 22.
[b] Source: Model results.
[c] Total electricity consumption and consumption per ton of rolled steel in kWh were converted to standard fuel using the countrywide average fuel consumption per kWh for 1975 of 340 grams reported in *Narodnoye khozyaystvo*, 1922-82, page 180. Because we used the countrywide average figure for fuel consumption per kwh, fuel and electricity consumption do not equal total energy consumption.

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- In a recent report the Soviets implied that about 75 mt of scrap was consumed in steelmaking in 1975; the difference between this level and that level estimated using the model was about 2 mt.

Cost of Producing Intermediate and End Products
Comparisons between the reported average cost and the computed shadow price of intermediate and end products also were used to validate the model. Specifically, we compared cost *(sebestoimost)* of electricity with the shadow price of electricity generated at captive power stations, and cost *(sebestoimost)* of steel with the shadow price of crude steel, both produced in open-hearth furnaces.[11] If the model accurately describes the Soviet iron and steel industry, shadow prices should approximate *sebestoimost* costs of resources and products reported by the Soviets:

- The reported average *sebestoimost* of electricity generated at Soviet thermal power stations in 1975 was 0.881 kopecks per kWh, well within the range of the computed shadow prices obtained using the model—0.709 to 0.912 kopecks per kWh—for electricity generated at captive power stations.[12]

- Differences between the actual and estimated costs of open-hearth steel produced varied from 0.3 percent in the most important region (Southern) to 13.5 percent in the Urals (see table 5).

Structure of Steelmaking
The similarity between the actual structure and the structure estimated using the model also were used to validate the model (see table 6). In both cases, open-hearth steel accounted for about two-thirds of total steel output. The share of basic oxygen steel estimated using the model exceeded the actual share by less than 1 percentage point; the estimated and actual shares of electric arc steel were roughly 10 percent.

[11] The *sebestoimost* of an input is the average cost of that input, including the cost of fuel and raw material resources, electricity, industrial steam and heat, depreciation of fixed plant and equipment, and labor. Unlike the "average cost" of a market economy, it excludes returns to financial capital.

[12] A. N. Shishov, N. G. Bukharinov, and others, *Ekonomika Energetiki SSSR* (Moscow: 1979), page 61.

Table 5
USSR: Ferrous Metals Industry: Actual and Model Cost of Producing Open-Hearth Steel in Major Producing Regions, 1975

	Actual [a]	Model [b]
	Rubles per metric ton	
Northwest	58.73	56.52
Southern	58.05	58.22
Urals	57.96	65.81
West Siberia	58.73	60.27

[a] Source: G. K. Bobylev and others, *Povysheniye rentabel'nosti proizvodstva v chernoy metallurgii,* Metallurgiya (Moscow: 1976), page 50.
[b] Source: Model results.

Operation of the Steel Industry in 1980

Soviet crude steel production was 148 mt in 1980—about 5 percent below the revised annual plan for 1980 of 155 mt and 10 percent below the midpoint of the original 1980 target of 160-170 mt. Much speculation exists concerning the relative importance of the two principal factors—inadequate steel furnace capacity and insufficient allocation of material resources to ferrous metallurgy—causing the crude steel production shortfall in 1980. In this section the model is used to estimate the relative importance of these causal factors. In addition, model results are used to estimate aggregate energy consumption and individual fuel use in 1980 and to assess Soviet energy conservation efforts in ferrous metallurgy in the 1976-80 Plan period.

Production

To estimate the relative importance of the two principal factors, we used a standard comparative analysis procedure. The quantity method calculates the production shortfall caused if estimated furnace capacity were less than intended or planned in 1980 and if estimated allocations of material resources were less than intended allocations in 1980.[13] The factor causing the largest absolute cut in production is the relatively most important causal factor.[14]

Our comparative analysis of the principal causes of the shortfall found inadequate steel furnace capacity to be the most important cause. The shortfall from the midpoint of the range of targeted crude steel output for 1980 of 165 mt caused by inadequate furnace capacity was 16.8 mt—50 percent greater than the 11.2-mt shortfall caused by insufficient allocation of material resources. Insufficient allocation of scrap metal was the most severe material resource constraint in 1980.

Energy Conservation

The 1976-80 Plan called for reducing energy consumption 8 percent per ton of rolled steel—from about 1,677 kg standard fuel (sf) in 1975 to about 1,550 kg sf in 1980. Results from the model suggest, however, that the Soviets consumed about 1,660 kg sf per ton of rolled steel in 1980; that is, 1 percent less than consumed per ton of rolled steel in 1975.

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The Soviets failed to achieve their energy conservation goals for 1980 in ferrous metallurgy primarily because they were unable to introduce energy-saving technological processes of ironmaking and steelmaking as rapidly as planned. For example, the planned

[13] These shortfalls are not additive because furnace capacity and material resources are complementary factors of production within a range of output. Nevertheless, the relative importance of these principal causes of a shortfall can be determined by comparing the extent of the shortfall attributable to each factor.
[14] The quantity method involves several steps. First, the maximum feasible planned level (MFPL) of steel production is calculated by holding both furnace capacities and resource allocations at the originally planned levels for 1980. Second, the shortfall in production caused by inadequate capacity is estimated as the difference between the MFPL and the maximum feasible level (MFL1) of production-holding capacities at estimated levels and resource allocations at the originally intended levels for 1980. Third, the shortfall caused by insufficient allocation of resources is estimated as the difference between the MFPL and the maximum feasible level (MFL2) of production-holding allocations at estimated levels and capacities at the originally intended levels for 1980.

Table 6
USSR: Ferrous Metals Industry: Actual and Model Structures of Steelmaking by Type of Furnace, 1975

	Actual [a]		Model [b]	
	Million metric tons	*Percent*	*Million metric tons*	*Percent*
Open hearth	92.4	65.4	91.3	64.6
Basic oxygen	34.8	24.6	36.0	25.5
Electric arc	14.1	10.0	14.0	9.9
Total	141.3	100.0	141.3	100.0

[a] Source: See United Nations ECE/STEEL/35, 1981, *Demand for and Supply of Metallurgical Coke for 1985.*
[b] Source: Model results.

share of steel produced in basic oxygen and electric arc furnaces was intended to increase to 32 percent and 12 percent, respectively, by 1980, while the open-hearth furnace share was scheduled to drop to 56 percent. But by 1980 open-hearth furnaces still accounted for over 60 percent of Soviet steel production, much more than in other major steel-producing countries, and basic oxygen and electric furnaces accounted for 29 percent and 10 percent, respectively. Moreover, production of continuous cast steel was 16 mt compared to the originally planned level of 22 mt.[15]

Production Prospects and Improvements in Energy Efficiency by 1985

We compare this estimate of steel production in 1985—also called the base case level—with the official target for 1985 and discuss the principal causes for the difference between the base case and target levels of production. Also, we estimate energy consumption in steelmaking in 1985 and discuss the prospects for improvements in conservation from 1981 through 1985. These estimates are derived using the model and the comparative analysis procedure discussed in the preceding section.

Production

The base case level of Soviet crude steel production in 1985 is nearly 156 mt—about 13 mt less than the 1985 target of 169 mt. This shortfall means that finished rolled steel output in 1985 will be roughly 9 percent less than the target of 118 mt unless the Soviets achieve substantial improvements in the yield of rolled steel products from crude steel.

The 8-percent shortfall in crude steel production will occur mainly because of inadequate capacity to produce the planned levels of material resources needed to meet both domestic requirements and export commitments. Inadequate crude steel furnace capacity will also cut production from the 1985 target, but this factor will be relatively less important.

The most important cause of the shortfall probably will be insufficient allocation of coking coal to ferrous metallurgy. The Soviets would need about 210-215 mt of coking coal to meet the original 1985 plan for steel production and to hold allocations to other uses at 1980 levels, including export commitments. To reach this goal, Soviet production of coking coal would have to increase by roughly 35 mt by 1985. If our estimate of mine depletion is reasonably correct, gross commissionings of new capacity would have to jump to roughly 170 mt during 1981-85—an unrealistic increase, [redacted]

In addition, we believe that Soviet production of iron ore will not exceed 255 mt by 1985—about 10 mt more than the 1980 total, but some 20 mt below the 1985 target. Furthermore, we project that the allocation of scrap metal to ferrous metallurgy will increase from about 78 mt in 1980 to 82 mt in 1985, or about 1 percent per year. [redacted] this allocation would have to increase to about 90 mt by 1985, roughly 3 percent per annum, to meet the needs of the steel industry in that year.

Using the quantity method, we estimated the expected shortfall caused by insufficient allocation of material resources at 12.6 mt of crude steel. The expected shortfall caused by inadequate steel furnace capacity was estimated at 7.1 mt of steel—less than 60 percent of that caused by the lack of material resources.

Energy Conservation

Although the Soviets have yet to announce their goal for energy conservation in steelmaking during 1981-85, it is unlikely to be less ambitious than that in the 1976-80 Plan. Assuming the Soviets planned a comparable (8 percent) cut in energy consumption per ton of rolled steel in 1985, they would consume about 1,527 kg sf per ton of rolled steel in 1985—133 kg sf per ton less than the estimated level of consumption in 1980.

Analysis based on results from the model suggest that the Soviets probably can save no more than 20 kg sf per ton of rolled steel in 1985, assuming the base case level of crude steel output. If the Soviets fulfilled both their crude steel production goal and their objective of increasing the share of basic oxygen furnace steel in total steel production, they would save about 25 kg sf per ton of rolled steel. We believe that because the Soviets will fail to achieve these goals they will probably not be able to reduce energy consumption per ton of rolled steel by more than 1 percent of the 1980 level to roughly 1,640 kg sf per ton.

[redacted]

Variations in the Outlook

This section compares results of the 1985 base case with alternative scenarios. Our major concern is the impact of a particular scenario on Soviet crude steel production in 1985. The scenarios studied are technological change in the coking rate, domestic policy change in the allocation of fuel oil to ferrous metallurgy, and change in the level of Polish coking coal exports to the USSR.

Improvements in the Coking Rate: A Technological Change

Technological progress in ferrous metallurgy has emphasized reducing the consumption of coke per ton of iron. Coke accounts for about 85 percent of the direct fuel use per ton of iron, and ironmaking accounts for more than 75 percent of total energy consumption in steelmaking.

The average consumption of coke per ton of iron (the coking rate) has declined continuously—falling from 725 kg in 1960 to about 540 kg in 1980.[17] The decline in this rate, however, has slowed in recent years, declining roughly 0.2 percent per year during the 1975-80 period compared with the longer term rate of roughly 1.5 percent during the 1960-80 period.

The purpose of this scenario is to assess the impact on Soviet steel production and fuel consumption in 1985 of a decline in the average coking rate at the 1960-80 trend-line rate of 1.5 percent per annum to 497 kg, rather than the rate assumed in the base case of 531 kg (the rate calculated using the 1975-80 trend-line rate of decline of about 0.2 percent per annum).[18]

[17] The coking rate for a particular year reported by the Soviets is an average rate based on coke required to produce both conversion and foundry iron. Conversion iron requires roughly 2 to 4 percent less coke per ton than is required to produce foundry iron.

[18] Lowering the average coking rate to 497 kg would indicate that the Soviets had achieved important changes both in the structure and operations of blast furnaces: increasing the average useful volume of blast furnaces by building new larger furnaces, by enlarging existing furnaces, and by retiring older, smaller, and economically more costly furnaces; increasing the iron content of the charge—perhaps, by increasing the proportion of pellets to sinter charge; and increasing the use of natural gas, fuel oil, and coal dust as well as the consumption of oxygen.

If we assume that the Soviets achieve a coking rate of 497 kg in 1985, they could increase steel output 2.3 mt above the base case level to about 158 mt and decrease coke consumption 1.4 mt—equivalent to saving 2.7 mt of raw coking coal. Moreover, lowering the coking rate to 497 kg could also decrease energy consumption per ton of rolled steel about 2 percent below requirements in the base case.

A Reduction in Fuel Oil Allocations: A Domestic Economic Policy Shift

A variety of domestic policies might be used to conserve energy and material resources in ferrous metallurgy. Cutting steel output, for example, would reduce the use of all resources. A less severe option would be to reduce the allocation of a single fuel or material resource. Because Soviet oil production is likely to stagnate by mid-decade, fuel oil is perhaps the most likely resource to be rationed more tightly in 1985.

If the fuel oil allocation were cut to 85 percent of consumption in the base case and assuming no reduction in use per unit of output, it would mean a loss of 1.7 mt sf—the total allocation declining to 9.5 mt sf from about 11.2 mt sf required to produce the base-case level of crude steel—156 mt. Reducing ferrous metallurgy's allocation of fuel oil 15 percent from the base case level would reduce both iron and steel production about 2 mt—more than 1-percent reductions from the base case level.

Impact on Fuel Conservation and on Interfuel Substitution. Because it would probably result to some extent in interfuel substitution, rationing fuel oil would not substantially change either total fuel consumption or fuel consumption per ton of rolled steel. Both the demand for metallurgical coke and natural gas would increase more than 2 percent with a 15-percent reduction in fuel oil consumption. As expected, the substitution possibilities are limited because these fuels are needed within narrowly defined limits in complementary steelmaking. We believe that the scope for reducing fuel oil consumption in ferrous metallurgy while maintaining steel output is quite limited. Consequently, steel output would have to fall if fuel oil allocations to ferrous metallurgy were cut considerably.

Impact on the Structure of Steelmaking and Transportation Requirements. Results of model simulations show that the structure of furnaces used to smelt crude steel would change with a reduction in the allocation of fuel oil. Those ironmaking and steelmaking processes that use fuel oil relatively intensively would be more costly to operate with reduced supplies. To the extent possible, the relative use of scrap metal would increase at the expense of pig iron in all steel furnaces. Moreover, reduced fuel oil supplies would force a cutback in steel production, first by reducing production of steel in open-hearth furnaces.

There would also be an increased burden on the already over-taxed Soviet railroad system from rationing fuel oil to ferrous metallurgy. Interregional flows of coking coal and pig iron would increase—more coal would move westward from Asian regions, especially to the Urals, and pig iron shipments of about 3 mt would move eastward for the first time, particularly from the Urals to Kazakhstan.

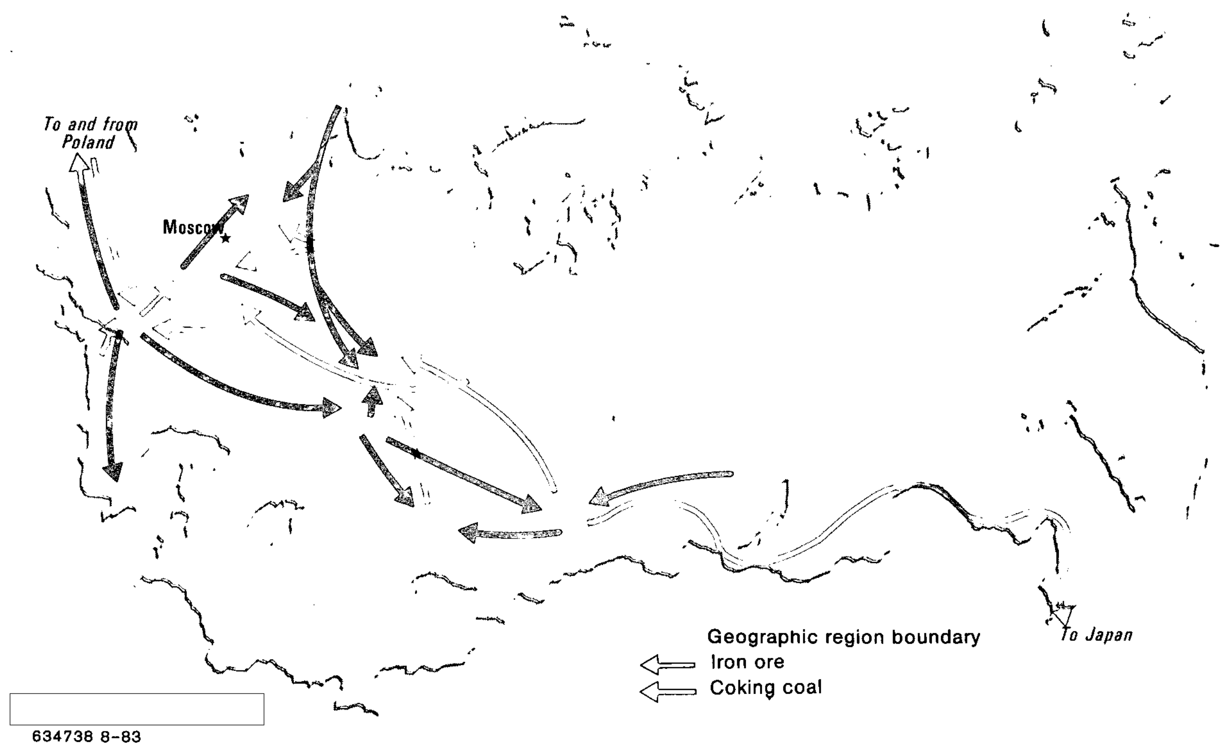
A Cutback in Imports of Polish Coal: An External Influence

The linkage between the economic growth of East European countries and energy supplies, especially oil imports from the Soviet Union, has been shown in recent studies to be extremely important. Less well understood is the linkage between the performance of the Soviet ferrous metals industry and economic conditions in CEMA countries.[19] Problems in the Polish hard coal industry, for example, can spill over into the Soviet steel industry.

Polish coal exports significantly affect Soviet iron and steel production, particularly at steel combines in the European USSR, and steel production during the 1981-85 Plan period could be hurt by disruptions in Poland. For example, Poland exported roughly 8 mt of

see Jonathan P. Stern, *East European and East-West Trade in Energy* (London: Policy Studies Institute and Royal Institute of International Affairs, 1982).

Figure 5
USSR: Iron Ore and Coking Coal Movements to Ferrous Metallurgy



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hard coal to the Soviet Union in 1979. This trade fell to 2 mt in 1981, and it is unlikely to return to the predisruption level during the 11th Five-Year Plan.[20]

Economic Costs. The costs of a complete stoppage of Polish coal exports to the USSR may be measured in terms of the adjustments required to reestablish efficient steelmaking operations without Polish coking coal, if we assume that bottlenecks in the Soviet railroad system do not interfere with the adjustment process. The major adjustments that would probably occur in 1985 are shifts in steel production among regions, changes in the structure of steel furnace use, and shifts in the volume and direction of shipments of raw materials resources among regions (see figure 5). Nonetheless, there probably would be a net loss in crude steel output from the base case level.

Our model estimates that crude steel production in 1985 would be cut to about 151 mt—down 5 mt from the base case level. The total shortfall from the 1985 target would be 18 mt, or 85 percent of the planned increase in output during the 1981-85 period.

Faced with the loss of Polish coal, the USSR might adjust by shifting certain steelmaking operations among types of crude steel furnaces and among regions of the Soviet Union. Soviet flexibility in

[20]It should be noted, however, that the USSR succeeded in expanding steel production in 1981 despite this cutback. This outcome could have resulted if the Soviets had reduced their strategic reserves of coking coal, reduced their consumption of this type of coal to produce electric power and heat, or altered their trade in coking coal with CEMA countries, or some combination of these options.

adjusting, however, depends heavily on the availability of additional railroad transport. Ferrous metallurgy, which currently enjoys a high priority in rail use, probably cannot count on much additional support from an already overtaxed rail system, and, if granted, this support probably would be at the expense of other sectors of the economy.

Impact on Other Sectors. Adjustments in regional steelmaking operations resulting from the stoppage of Polish coking coal in 1985 would ultimately change the volume and direction of railroad freight shipments of fuels and raw material resources—the most important affecting coking coal and iron ore. Interregional shipments of coking coal and iron ore would increase dramatically. For example, extremely long-haul coal shipments from West Siberia to the Central regions—nearly 3,500 km—would increase more than fortyfold to about 13 mt, and short-haul ore shipments from deposits at Rudnyy in Kazakhstan to combines in the Urals—a distance of 350 km—would increase 12 percent to 18 mt. Thus, cutbacks in imports of Polish coal would significantly increase the burden on the already overtaxed Soviet railroad system.

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